How the ICU Follows Orders: Care Delivery as a Complex Activity System

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Abstract
In this paper, we use the theory of distributed cognition to understand work practices in terms of the behavior of an activity system. We do so by detailing the roles that local representations of information play in the social, cognitive, organizational, and technological processes that accomplish task work. Specifically, we characterize a portion of the medication order process in an Intensive Care Unit. In this setting, the processes that execute a medication order have evolved to accomplish the primary tasks of medication administration and also to simultaneously support other important aspects of the unit's work. Designers of systems that centralize and automate information resources must consider the diverse and latent roles played by information in order to improve design and to anticipate how their products affect complex care delivery systems.

Introduction
We describe the medication order process within an Intensive Care Unit (ICU) using the theoretical framework of distributed cognition [1,2,3,4]. Our unit of cognitive analysis is an activity system, which is composed of a group of human actors, their tools and environment, and is organized by a particular history of goal-directed action and interaction. This history is responsible for the knowledge structures, social roles, and cultural values which make day-to-day activities routine, meaningful, and predictable. The ICU represents a situated activity system that accomplishes many goals in its work; the orders process is but one aspect of that system.

To understand how safety emerges from the work accomplished by this activity system, we spent 12 months conducting a cognitive ethnography of a 14-bed medical and surgical ICU in a mid-size hospital that is part of a large HMO. Using ethnographic methods, we observed how information was exchanged and used to generate system behavior, and we were able to assess the influence of various structures and processes within the system by asking situation-specific questions of actors. We paid careful attention to the structures and processes that propagate information through the system and how these influence action and thus system behavior. Drawing upon this research, we shed light on how the ICU as activity system implements an order process and discuss what it may mean for the design or introduction of automated information systems such as computerized physician order entry.

Background and Methods
Medication administration is one of the care team's primary means for intervening to correct a patient's unstable or critical state in an ICU. However, the medications used in critical and acute care settings can also be dangerous. Accordingly, many patient safety efforts are directed at this aspect of health care [5].

We observed cardiac and critical care activities within the ICU of one hospital using the methodology of cognitive ethnography and the theoretical framework of distributed cognition. The ICU observers (Hazlehurst, McMullen) are cultural anthropologists with extensive training in ethnographic methods. We spent more than 700 hours in this ICU over a 12-month period, observing care activities, situations, and processes. Whenever possible and appropriate, we would engage staff in informal conversations that allowed us to follow up on observations or expand our understanding about the factors organizing care behaviors and situations. We recorded these observations and conversations on small notepads and then returned to our office, where we typed up expanded "field notes" of these observations. We also collected and analyzed artifacts of the workplace such as protocols, guidelines, policies, and charting forms that organize care activities.

We treat the ICU as a complex activity system that exhibits behaviors according to its specific internal organization. The method for understanding this relationship is borrowed from cognitive science, which has a long history of studying the relationship between individuals' internal organization and their behaviors in terms of information processing properties implemented by the central nervous system. However, distributed cognition treats the activity system, rather than the individual, as the unit of cognitive analysis. In particular, we apply the concept of computation as the "propagation of representations" [2,3] through the system to explain its behavior. A representation is an information-bearing structure that can play some functional role in a process within the system [4]. Processes propagate representations and produce information-bearing structures to achieve effects within the environment. System behavior results from the co-dependent operation of these processes, together with the structures that they produce and which may be imposed upon them by the environment. Fortunately for us, and in contrast to research on individual cognition, the representations and processes that are of interest within the ICU are often visible (i.e., they are not all hidden in the functioning of individual minds).

Cognitive ethnography entails mapping out how representations are propagated through the system under different circumstances and with what effect. This requires capturing specific details about work tasks, about how information gets used to solve tasks, and about how new kinds of information are produced in the process. Our ethnographic methods consist of focused and general field observations in the tradition of anthropological fieldwork. We generally observed patterns in daily routines within the unit (e.g., charting methods, staffing and admit decisions, unit leadership practices, transferring patients, multi-disciplinary rounds, and interactions among different specialists). Other observations focused on the organization of specific tasks, tools, information resources and care situations. We also conducted tape-recorded, open-ended interviews with staff to get their own words and propositions about how things work, and to cover topics that we could not observe.

Analysis and Findings

One simple description of the medication order process envisions a sequence of two or three discrete steps. In this model, orders are created by a physician (Step 1) and are then carried out by the responsible nurse or care team (Step 2). A slightly more complex model would consider the problem of obtaining or provisioning the medication (Step 1a), which is typically thought of as a pharmacy function. These simple models of how medication orders work make the concept of computerized physician order entry (CPOE) so compelling [6,7]. In particular, these models, taken together with general assumptions about the role of information technology, imply the following propositions: 1) CPOE will make the treatment plan explicit (i.e., what needs to be done will be unproblematically understood) by making the information self-explanatory and unambiguous; and 2) execution of the care plan will be unproblematic once it is unambiguously represented in the CPOE system because the plan is always available to be consulted. These propositions do not accurately reflect the role of information in the non-automated setting we studied, nor do they square with our theoretical understanding of human cognition. Furthermore, analysis of CPOE adopters' self-reports about their experiences demonstrates the issues: clarity is perceived but not assured; availability is assured but not necessarily helpful [8].

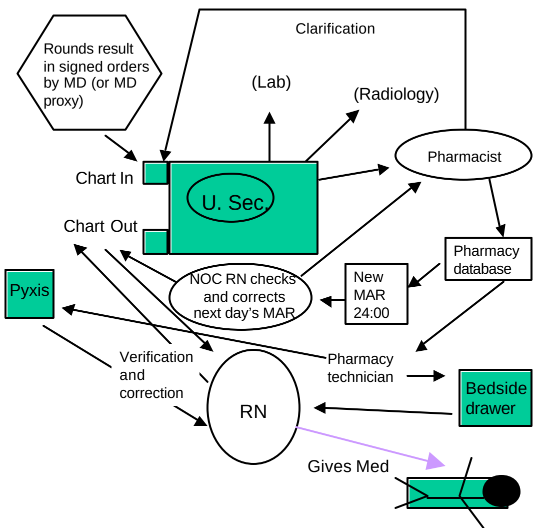
<u>The orders process as situated activity:</u>

The actual medication order process is much more complicated than a three-step model can possibly represent [7]. In the ICU, the order process contains steps that facilitate many interfaces between specialists whose roles are essential to making things work for each patient and for the unit as a whole. By "specialist," we mean to highlight both naturally occurring and designed divisions of responsibility and action along lines of experience, profession, social status, personality, and other features. The steps in our more complex picture of the order process are organized by a canonical sequence, but the process is hardly linear. Indeed many of the steps are either designed or have evolved to create feedback loops that serve many purposes. They catch and correct mistakes, modify clinical practice, train novices, maintain communication channels and divisions of labor, and accommodate unexpected events and real-world complexities.

Figure 1 shows some of the pathways of information that define the way medication orders get done in this ICU. We have only tried to depict the process that begins with the writing of a single medication order. The system is actually much more complex, in part because it accommodates multiple orders per patient per day, but also because there are other starting points for activity in the system.

The figure uses ovals to represent actors in the system (RN Responsible for patient, Night Shift or "NOC" RN, Pharmacist, and Unit Secretary). The figure uses rectangles to represent tools, types of information and environmental structures (the Pyxis/medication dispenser, the bedside meds drawer, the pharmacy computer system, the Medication Administration Record or MAR, which is created by hand when a patient arrives in the ICU and then subsequently printed by the pharmacy computer system at midnight to form the next day's medications record). Finally, the figure uses arrows to represent flows of information. Some of these arrows are labeled with specific functional properties that are achieved by the flow of information. As stated above, we treat these flows of information in terms of the "propagation of representations" [2,3] through the system that explains the system's behavior.

Figure 1: Propagation of medication orders in the ICU activity system.



To take one example of how representations propagate through the system, consider the role of the unit secretary (US) in the medications order process. The US performs the function of "pulling orders" from the patient chart once it has been deposited in the "Chart In" box near her desk to indicate that new orders were written. She then transcribes and distributes the received information out to the various entities or actors that are expected to act upon the information in some way. However, the US's actions are more than simply a physical transfer of information. US will often "expand" upon the order, for instance by incorporating a pre-printed care protocol that specifies a specific set of steps but is referenced by a single order. These protocols represent an understood and packaged set of care activities for staff in the unit, and their incorporation here both simplifies the steps needed to create an order and also ensures conformity to understood methods for implementing the order. The US may also "repair" the information because she happens to notice an inconsistency with some other piece of information or because the order is incomplete in some manner.

The activity performed by US often has consequences for the system's behavior that are ancillary to the role she plays here as distributor of the order. These consequences include: establishing and learning shared practices in the unit; learning about individual providers' idiosyncrasies; catching mistakes that correct an order or modify the process itself; and creating situation awareness amongst the staff because the secretaries' function and workstation serve as a central "hub" for questions and answers.

Case study: implicit consequences of the orders process. The following brief description of an exchange regarding the interpretation of ambiguous medication orders, here distilled down to the essential interactions among unit staff, exemplifies some of the implicit consequences of the orders process within this system. In this example, two nurses who are caring for the same patient during the overlap between their shifts notice ambiguities in the MAR that lead them to investigate two orders for clonidine in a patient's chart. This investigation entails an active search through the chronological record, evidenced in the orders paperwork and contained in a binder that holds the patient's chart. This paperwork generated the MAR (see pathway in Figure 1) and also represents a history of actions taken up to this current point in time.

Nurse 1 on evening shift is checking orders in bed 9's chart. Nurse 2 is caring for the same patient on day shift. Nurse 1 stands by Nurse 2 at the secretary's desk. Nurse 1 sees two rows on the MAR for clonidine, with different administration times. One row has clonidine BID [twice daily]. A lower row, added to the MAR later in the day, shows an entry for clonidine HS [at bedtime]. Nurse 1 asks Nurse 2 how to change the MAR to correctly reflect the output of two orders written by the cardiologist – one as BID and a later order as HS. In the HS order, the physician did not indicate that he was making a "change order." Nurse 2 suggests interpreting the orders by using a yellow highlighter indicate that the BID order was discontinued or held. The two nurses and the unit secretary, who is standing nearby, all reference the convention that "You go by the most recent order." The pharmacist steps into the conversation to let Nurse 1 know about another ambiguity in the cardiologist's orders. The cardiologist ordered lovenox using the date for the following day. The pharmacist was writing a routine order clarification, with the dosage of the drug calculated according to the pharmacy protocol. Given the conventions for lovenox administration, the pharmacist suspects that the cardiologist intended to administer lovenox that day, not the following day. The nurses agree with the pharmacists' assessment, but all feel that they should confirm this with the physician. The pharmacist says that he has already paged the cardiologist regarding the lovenox order, and Nurse 2 asks the pharmacist to mention the clonidine issue as well. The nurses confirm with each other that the pharmacist will address both issues when he talks to the cardiologist.

Discussion

The brief example above exhibits many facets of the roles that information and information processing play in organizing system behavior. The interaction clearly shows that the MAR, which in this instance deviates from normal practice, is a representation that does many different kinds of work. Providers in the unit have organized themselves with respect to the MAR, and thereby with respect to each other and their task work, in a fashion that makes the deviation noticeable and creates learning. The deviation leads to noticing, the noticing identifies a possible mistake that can be read from the history of paperwork, and the conversation leads to shared awareness about a possible second mistake. The actors involved create a comprehensive and efficient plan for reconciling the discovered discrepancies. The whole interaction reinforces shared practices for properly treating ambiguous information and recovering from deviations in expected practice. Such opportunities for group discussion about features of the practice are essential to the system because they create the process that can repeat this type of error-correcting function over and over again.

Some might see the existence of "duplicate information" in various places as a mandate for "cleaning things up" by creating single and apparently complete representations of order information within an automated order entry system. Similarly, some might consider inefficient and chaotic the multiple processes that manipulate and represent this information for local purposes within the unit. These views would advocate elimination of multiple and local versions of information since the centralized computer system could deliver it unambiguously and on demand.

We caution against such conclusions by showing that the information that organizes system behavior is not adequately defined in terms of its standalone "clarity" or "availability." We have demonstrated that robustness in performance of this activity system relies upon information playing many different roles within the system. Co-dependent processes use specific representations entailing redundant and sometimes ambiguous information. And yet, the envisioned benefits of CPOE stem from the inference that centralized representations will enable less error-prone and more effective processes for implementing the physician's treatment plan.

Illegible handwriting, non-standard use of language, and the overhead associated with paperwork activities are undesirable barriers for safe and efficient care processes. However, the usefulness of paper as an information processing medium in work practices have been demonstrated in observational studies of air traffic controllers [9], civil engineers [10], clinicians in the ICU [11], as well as in the laboratory [12]. We believe that eliminating established representations and interpretive processes removes functional properties that are essential to the performance of the activity system. This happens because multiple and co-dependent interpretive processes within the system have become organized to attend to and act upon specific local representations.

Although space limitations prevent us from demonstrating our conclusions with extensive examples, below we identify a number of important properties of the ICU activity system based on our ethnographic research. These properties follow from the existence of multiple and process-specific representations within this activity system:

- Robustness in system performance: Redundant representations encode similar information in different forms utilizing multiple kinds of media. This makes the information available to distinct but interrelated interpretive processes. Such redundancy ensures robustness and correctness in the functions performed by the system.
- Reach of the system: "Reach" indicates the breadth and depth of information that the system takes in and acts upon. Multiple representations, and the diverse processes that employ them, expand the "reach" of the system.
- Co-construction of meanings: When multiple, yet co-dependent and coordinated interpretive processes exist within a system, these processes can jointly construct meaning. Nurses maintain information about their patients on personal pieces of paper (commonly referred to in the unit as their "brains"). The nurse's personal information may lead him or her to challenge assumptions and decisions based on other representations of patient information. The information may be similar, yet each representation may encode different features of local relevance to each interpretive process. The best action for the patient may well result from a reconciliation of these alternative constructions of the state of affairs.
- Engagement by actors: Actors in distinct roles each control and manipulate their own representations. This facilitates engagement of task work and thereby focuses attention upon issues that ensure proper system functioning.
- Support for a division of labor: Because multiple representations support distinct interpretive processes within the system, the system can maintain a distribution of labor. This

distribution of labor enables different actors to specialize in different but co-dependent aspects of care for the patient.

- Enhancing situation awareness: Task work yields many opportunities for actors to become aware of situations that may unexpectedly require their attention in this complex workplace. These opportunities are enhanced by the aforementioned ways that multiple representations support task work. Actors are more engaged, and the coordination demands of task work (involving negotiation of the meanings of information resources) create interactions that communicate situational information.
- Learning the parts of the system: The internal organization and workings of this activity system require methods for imparting operational knowledge to novices who enter into the system. This learning is made possible by a system that has co-dependent component processes involving representations tuned to the needs of those components as well as actors in various roles attending to these processes as part of their task work. Such a system can reproduce itself in the face of turnover of individuals, practices and technologies within the system.

We have outlined a scientific theory and method for describing the ICU as an activity system, whose behavior is predicated on the propagation of representations in the conduct of specific tasks to accomplish shared goals. This approach to understanding system behavior is founded upon the idea that co-dependent interpretive processes are coordinated in complex ways through the manipulation of representations. Introduction of CPOE will centralize these representations, and thereby reconfigure these interpretive processes and overall system behavior. Although the activity system can organize itself anew around CPOE, we believe that the consequences of centralizing this information are poorly understood [13]. As with the introduction of other centralizing technologies in health care [14], we expect CPOE to incur many unanticipated consequences. We believe that distributed cognition and cognitive ethnography can be productively applied to effectively explain and possibly predict some of these consequences. At the very least, designers of CPOE technologies would do well to understand their product as a component of an activity system in order to mitigate unintended consequences, to have their products adopted by users, and to make their products more useful to actors in the system.

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